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ATM SEC CAMERA TUBE SPARES PROGRAM

NAS 8-29063

FINAL REPORT

ELECTRONIC TUBE DIVISION
ELMIRA, NEW YORK 14902

ATM SEC CAMERA TUBE SPARES PROGRAM

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APOLLO TELESCOPE MOUNT

SEC CAMERA TUBE SPARES PROGRAM

FINAL REPORT

Prepared for:

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HUNTSVILLE, ALABAMA 35812

CONTRACT NAS 8-29063

by:

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1. INTRODUCTION AND SUMMARY

In July 1967, under Contract NAS 8-20860 from the Marshall Space Flight Center, the Westinghouse Electronic Tube Division began the development of a low-light-level SEC camera tube for the Apollo Telescope Mount. Development of this tube, designated the WX-30691N, was completed in October 1967. During 1968, the tube was put into production and thirty-two (32) flight-quality tubes from four (4) environmentally qualified lots were shipped to NASA in fulfillment of the contractual requirements. Two of these tubes are, at the time of writing, performing their specified function in the solar telescopes of the Skylab orbiting space station.

In 1972, four years after the original production run and approximately one year prior to the Skylab launch, the Marshall Space Flight Center identified a need for additional WX-30691N tubes to be used as spares for the ATM cameras. This report describes the ATM SEC Camera Tube Spares Program. This was initiated at the Westinghouse Electronic Tube Division to meet the NASA requirement for ten (10) additional WX-30691N tubes of flight quality.

Work on the ATM Spares Program (Contract NAS 8-29063) began in July 1972. The production run was made from November 1972 through March 1973. Ten (10) WX-30691N flight-quality tubes were shipped to NASA in fulfillment of the contractual requirement. These tubes came from two environmentally-qualified lots. In addition to the 10 flight tubes, 14 flight candidates (full specification tubes from non-qualified lots) and 62 other operable tubes were also delivered to NASA.

A total of sixty-eight (68) standard WX-30691N tube starts and twenty-eight (28) WX-30691BRN starts with mesh-supported targets were made during the present production run. None of these latter tubes was delivered as a flight-qualified unit due to the incomplete qualification status of lots 101 and 102. However, many of the WX-30691BRN type were delivered as flight candidates or other operable tubes. They will permit NASA to evaluate the characteristics of the mesh-supported SEC target which offers improved ruggedness and a greater degree of resistance to over-exposure damage.

An important engineering improvement was made during the Spares Program. The thermionic cathode structure was modified to bring the cathode temperature to a more suitable value and shields were placed over the glass-to-metal interface of the stem leads to reduce the possibility of interelectrode leakage. The cathode temperature change has resulted in a corresponding change in the recommended operating conditions for the heater of the thermionic cathode. All tubes built during the 1972-1973 ATM Spares Program should be operated with a heater current of 150 mA (6.3 volts). Operation at lower currents and voltages may adversely affect the life of these tubes.

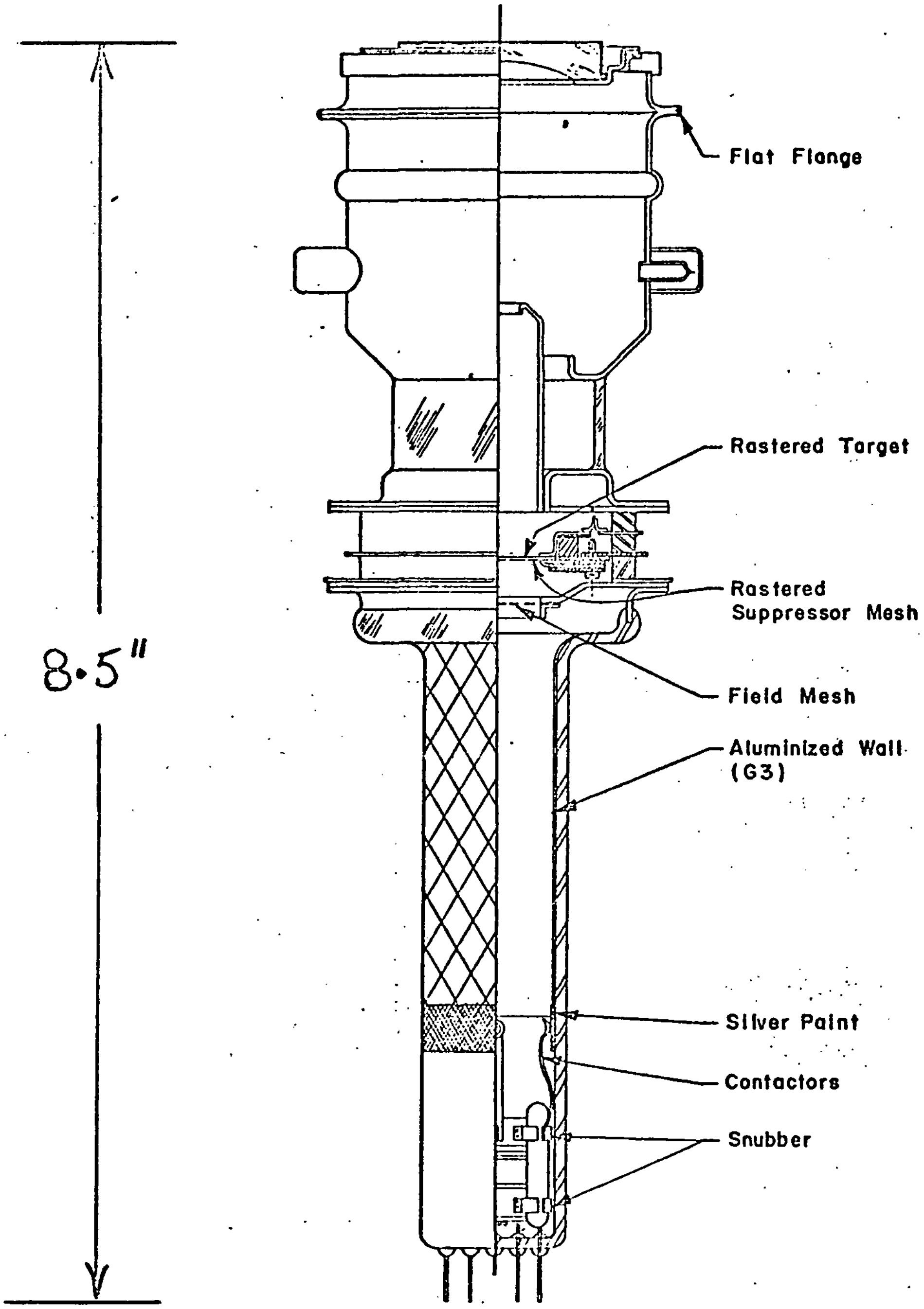
2. REVIEW OF MANUFACTURING SPECIFICATION

2.1 Description of the WX-30691N Camera Tube

The WX-30691N/WX-30691BRN tube, shown in Figure 2.1, is a sensitive, compact SEC television camera tube with an electrostatically-focused image section and a magnetically-focused and deflected reading section. The WX-30691N was developed under NASA Contract NAS 8-20860. The feature which distinguishes SEC tubes from the older types of camera tubes is the Secondary Electron Conduction (SEC) target. This target has high gain, long storage, and retains only a small percentage of its stored signal after a single scan of a reading beam. The electrostatic image section remains in focus for all photocathode voltages. Thus, varying photocathode voltage provides a convenient means for gain control. The reading section is similar to the electron gun of an all-magnetic vidicon. A detailed description of this tube can be found in the final report for NASA Contract NAS 8-20860.

2.2 Update of Tube Manufacturing Specification

The tube manufacturing specification was found to be out of date when it was reviewed at the start of this program. Many advances in tube technology had been made since the last ATM tubes were built in 1968. A proposal for incorporating these advances into the specification was prepared by Westinghouse and approved by NASA. Some of the more significant improvements were:



WX-30691N/WX-30691BRN SEC CAMERA TUBE FOR THE APOLLO TELESCOPE MOUNT

FIGURE 2.1

(1) The thermionic cathode structure was modified to bring the cathode temperature to a more suitable value. As noted in the introduction, this change has resulted in a corresponding change in the recommended operating conditions for the heater of the thermionic cathode. All tubes built during the 1972-1973 ATM Spares Program should be operated with a heater current of 150 mA (6.3 volts). Operation at lower currents and voltages may adversely affect the life of these tubes.

(2) The cathode material was changed to reduce the possibility of damage during gun bulb and gun stem sealing.

(3) The G_1 electrode was modified in shape to improve gun efficiency and vents were added to the G_1 and G_2 electrodes to improve out-gassing.

(4) Shields were placed over the glass-to-metal interface of the stem leads to reduce the possibility of interelectrode leakage.

(5) Increased getter flash was used to improve the tube vacuum conditions. Other minor part and process changes were also incorporated into the specification.

2.3 Tube with Mesh-Supported Target (WX-30691BRN)

As a result of a proposal from Westinghouse, NASA requested that two of the tubes to be shipped as deliverable items should incorporate mesh-supported targets in place of the conventional aluminum-oxide target substrate. The tube with the mesh-supported target is designated the WX-30691BRN in recognition of its increased Burn Resistance. The mesh-supported target was developed by Westinghouse to:

(1) Reduce microphonics during vibration.

(2) Increase the target's tolerance of mechanical and electrical shock.

(3) Increase the target's tolerance of a signal overload.

The burn characteristics of both the standard and BR tube are described in Appendix 1 of this report.

The external appearance and operating voltages of the WX-30691N and the WX-30691BRN are identical. Internally the tubes differ only in the target structure. The shapes of the target supports for the respective tubes are identical, but they are made of different materials so that they will match the thermal expansion of the substrates. The details of the two target structures are given below in Table 2.1.

Table 2.1

	WX-30691N	WX-30691BRN
Target support material	Kovar	Inconel
Substrate	Aluminum film evaporated onto an aluminum-oxide film	Aluminum film laid on copper mesh

The procedure for making the target support assembly for the WX-30691N is as follows:

(1) Attach an aluminum-oxide film to the target support.

(2) Evaporate an aluminum film onto the aluminum-oxide.

The procedure for making the target support assembly for the WX-30691BRN is as follows:

(1) Braze a copper mesh to the target support.

(2) Lay an organic film over the copper mesh.

(3) Evaporate an aluminum film onto the organic film.

(4) Remove the organic film.

3. TUBE MANUFACTURING ACTIVITY

3.1 Scope of Production Run

The first 14 weeks of the contract from July to October 1972 were spent in preparing for the production run. During this time, parts were purchased, traceability was established, and subassemblies were manufactured. The production run was begun in November 1972 and completed March 1973. A total of sixty-eight (68) WX-30691N and twenty-eight (28) WX-30691BRN tube starts were built during this period. The results of the production run are summarized in Table 3.1.

3.2 Causes for Rejection

Table 3.1 provides an analysis of tubes that failed to meet the flight tube specification. It should be noted that the numbers listed under the "Rejection Analysis" heading in some cases add up to a total larger than the number of tube starts in the lot. This is because some tubes fail for multiple causes. The following is an expanded description of the causes for rejection noted in Table 3.1.

Blemishes - Spots and streaks from all sources (target, photocathode, and mesh).

Poor Uniformity - Nonuniformity greater than 25%.

Field Emission - Arcing or field emission in the image section.

Arcing - Arcing in the gun section.

Table 3.1

SUMMARY OF PRODUCTION RUN

Lot No.	Production Period (11/72 to 3/73)	Quantity & Type of Tube Starts	Lot Qualification Status	Rejection Analysis							Disposition of Tubes				
											Shipped				Scrapped
				Blemishes	Poor Uniformity	Field Emission	Arcing	Low Photoresponse	Target Defects	Other	Flight Tubes	Flight Candidates	Operable Rejects	Qualification Tubes	
1	11/3 - 12/13	30 WX30691N	Passed	8	4	2	7	1	4	7	4	0	-	3	-
2	12/29 - 1/25	19 WX30691N	Passed	5	5	4	1	1	7	0	6	1	-	1	-
3	1/25 - 2/5	9 WX30691N	Failed	3	1	0	0	0	0	1	0	4	-	2	-
4	2/5 - 2/9	10 WX30691N	Incomplete	2	3	0	0	0	1	2	0	3	-	1	-
TOTALS (lots 1 to 4)		68 WX30691N	--	18	13	6	8	2	12	10	10	8	32	7	11
101	2/23 - 3/7	18 WX30691BRN	Incomplete	6	4	1	0	1	4	0	0	4	-	1	-
102	3/13 - 3/16	10 WX30691BRN	Incomplete	1	6	0	0	0	5	1	0	2	-	0	-
TOTALS (lots 101 to 102)		28 WX30691BRN	--	7	10	1	0	1	9	1	0	6	20	1	1
GRAND TOTAL		96	--	25	23	7	8	3	21	11	10	14	52	8	12

Low Photoresponse	-	A photoresponse which is judged to have led to rejection for inadequate overall tube sensitivity (less than 30 μA/fc).
Target Defects	-	A defective target which is judged to have caused rejection for grain, high lag (greater than 10%), or low sensitivity (less than 30 μA/fc).
Other	-	Mechanical defects and exhaust scrap.

The engineering effort undertaken to control and reduce tube failures noted above is discussed in Section 4 of this report.

3.3 Summary of Tube Shipments

As Table 3.1 indicates, tube shipments were divided into three categories: flight tubes, flight candidates, and other operable tubes.

Flight Tubes - Ten (10) Units Shipped

The contract called for the delivery of ten (10) flight tubes, eight (8) WX-30691N and two (2) WX-30691BRN. Due to the failure to qualify a WX-30691BRN lot, and after permission was granted by NASA, ten (10) WX-30691N tubes from qualified lots were shipped in satisfaction of the contractual requirements. The following WX-30691N tubes were shipped from qualified lots after verification from the local resident government inspector that they met the Flight Tube Specification 50M12768 (with the modifications noted in the contract).

Table 3.2

Serial Numbers of Flight Tubes

Lot 1	Lot 2
72-43-025	72-48-141
72-48-121	72-48-142
72-48-127	72-48-159
72-48-129	72-48-164
	72-48-153
	72-48-155

Flight Candidates - Fourteen (14) Units Shipped

A total of fourteen (14) tubes, eight (8) WX-30691N and six (6) WX-30691BRN, were shipped as flight candidates. These tubes were shown by tests at Westinghouse to meet all the requirements of the Flight Tube Specification 50M12768 (with the modifications noted in the contract), but they do not have lot qualification or test approval by the local resident government inspector.

Other Operable Tubes - Sixty-Two (62) Units Shipped

A total of sixty-two (62) other operable tubes were shipped to NASA-Huntsville. These consisted of thirty-nine (39) WX-30691N tubes and twenty-one (21) WX-30691BRN tubes in the operable reject and qualification tube category from the production run, and two (2) WX-30691N tubes which were made as engineering starts.

4. ENGINEERING ACTIVITY

4.1 General Discussion

After the initial update of the manufacturing specification, the major engineering effort on the WX-30691N was directed to improving manufacturing yield. Some engineering effort was also required to introduce the WX-30691BRN into production.

Table 3.1 shows that the major failure items were blemishes, non-uniformity, and target defects. Arcing between the field mesh and suppressor mesh was also a major failure item until the cause of this problem was identified and eliminated.

4.2 Arcing and Field Emission

The arcing problem was originally believed to be occurring in the image section of the tube (the portion of the tube between the photocathode and the anode). However, further testing showed that the arcing was between the field mesh and suppressor mesh connections. A set of experiments was run to determine the cause of the arcing. They were:

(1) Complete the soldering operations after testing tube for arcing. This test was to check if flux on the ceramic between the mesh connections caused the arcing. Very little effect was observed and the practice was discontinued.

(2) Reverse the direction of the screws used to mount the suppressor mesh on the ceramic. This test was to check if the arc occurred between these screws and the field mesh. No effect was observed and the practice was discontinued.

(3) Apply chrome oxide to the inside of the ceramic between the mesh connections. This test was to check if the arc occurred across the inside of this ceramic. This practice eliminated the arcing and was used on the remaining tube starts.

Thus, the solution to the arcing problem was found to be coating the inside of the ceramic between the field mesh and the suppressor mesh connection with chrome oxide.

In the process of solving the arcing problem, it was also found that the chrome oxide in the image section was unnecessary and could be eliminated. As noted above, the first cases of arcing were mistakenly analyzed as a form of breakdown in the image section (the portion of the tube between the photocathode and the anode). In response to this idea, a test was run comparing tubes with and without chrome oxide oxide in the image section. It was found that tubes without chrome were less likely to have field emission than tubes with chrome oxide. Also, image sections which have been coated with the chrome oxide formulation, which is used on glass, cannot be cleaned as well as uncoated bulbs. For these reasons, use of chrome oxide in the image section was discontinued.

Fortunately, the type of chrome oxide used on ceramics can be stringently cleaned; hence, it does not affect the blemish characteristics of the tube. However, it did cause the lag to increase. A minor modification of the processing schedule (discussed in the following paragraph) eliminated this effect.

4.3 Target Defects

Defective targets cause a tube to be rejected for grain (or fixed pattern noise), high lag, or low sensitivity. The predominant target defect observed in the WX-30691N was high lag. This problem became severe for a short time in lot 2 when the chrome oxide was first used in the ceramic. Excessive lag was eliminated by storing the painted ceramic in a warm, dry atmosphere for at least 16 hours just before it was used.

Grain and high lag were serious problems in the WX-30691BRN; 33% of the WX-30691BRN tubes were rejected for these defects alone. Seven out of nine of the tubes which were rejected for these defects were made on two days. 88% of the tubes made on those two days failed for grain or high lag. A defective dryer (which controls the humidity of the atmosphere in which the tube is assembled) was found later; it had caused similar problems in similar tube types. This dryer could have caused the problem that was observed.

4.4 Non-Uniformity

Non-uniformity in the WX-30691N and WX-30691BRN results from the original design compromises. The trade-off is between uniformity and vibration performance. The target substrate was made rectangular and as small as possible to improve vibration performance. Since uniformity performance deteriorates rapidly near the edge of the substrate, reducing the size of the substrate decreases the signal uniformity. The rejection rate of tubes for poor uniformity was 19% in the WX-30691N. Due to the difference in the substrate, the WX-30691BRN has a greater problem with uniformity than the WX-30691N. The rejection rate of tubes for poor uniformity was 36% in the WX-30691BRN.

One experiment was run on the WX-30691BRN to try to improve the uniformity. It was found that the target substrate was forced to be slightly off center due to the interference between the welding lug on the target support and the target pin. Consequently, the edge of the target substrate was very close to the edge of the image, resulting in poor uniformity on that side. The target was centered by shortening the lug which was interfering with the target pin.

4.5 Blemishes

Blemishes are one of the major shrinkage items in all SEC tubes. Twenty-six percent of the WX-30691N tubes and WX-30691BRN tubes failed for this problem. Continuing efforts are being made to reduce blemishes. One such effort was omitting the chrome oxide from the image section. As a result, it was possible to do a better job of cleaning this part of the tube.

4.6 Low Photoresponse and Other Defects

The photoresponse was a very low failure-rate item during this production run. Only 3% of the tubes failed for this problem. However, it was found that the thermionic cathode aging was causing the photocathode to lose sensitivity during the aging process. Consequently, the thermionic cathode aging was done before the tube was removed from the exhaust station.

Miscellaneous other defects were not a major failure item after a short learning period had been experienced. The failure rate for these defects was 23% for lot 1 and only 6% for lots 2 through 102. No ion spots were observed during the whole production run. This good performance was due to the increased getter flash, resulting from the changes made during the initial tube update, and improved processing of parts.

5. LOT QUALIFICATION

5.1 Description of Procedures

Sample tubes from each of the production lots were subjected to environmental tests in accordance with the end-item test plan. The tests included high and low temperature operation, thermal shock, altitude, sinusoidal and random vibration, mechanical shock, acceleration, and acoustic noise environments.

In all cases, the lot qualification tubes were sub-specification tubes. Their defects were judged to have no correlation with the ability of the tubes to survive the environmental tests. These tubes were dynamically aged and tested in the same manner as tubes which were to be shipped in fulfillment of the contract. The tubes received a final electrical test (the test performed on all shipped tubes) both before and after the lot qualification tests. Thermal, mechanical shock, and altitude tests were performed at the Westinghouse Electronic Tube Division, Elmira, New York. The acceleration and vibration tests were performed at the Associated Testing Laboratories facilities in Burlington, Massachusetts, and the acoustic noise tests at Noise Unlimited, Somerville, New Jersey.

The tubes were subjected to the specified vibration and mechanical shock tests while mounted in the fixture described in the Final Report of the ATM SEC Camera Tube Program (NASA Contract NAS8-20860). The

fixture allowed slight compression of the tube image section and also locked-in the tube stem by means of an "O" ring clamp assembly. Before subjecting the tube to the vibration and shock tests, the image section of the tube was potted in silicone rubber (G.E. RTV 511).

5.2 Status of Tube Lots

Lot 1, WX-30691N

All the environmental tests were passed by the lot qualification tubes. One tube (72-48-115) was used for the thermal test. A second tube (72-43-029) was used for the shock test and vibration test. This tube arced in the electrical test set after it had been vibrated. This arcing was found to be between the field mesh and suppressor mesh and is discussed in Section 4.2. It was shown that 72-43-029 passed the electrical test after vibration and before the arc. A third tube (72-48-113) was used to repeat the vibration test (at 85% of the primary level as is specified for the secondary vibration tube) and to finish the environmental tests. The vibration test was repeated even though it was considered unlikely that the arcing resulted from the vibration.

Lot 2, WX-30691N

All of the environmental tests were passed by the lot qualification tube. These tests were made on one tube (72-48-146). As requested by NASA, the thermal tests were run before the vibration tests. This

order was chosen to assure NASA that the thermal tests did not loosen the mesh and the target substrates, thereby causing the tube to fail vibration tests.

A minor decrease in sensitivity (45 μA/fc before the thermal tests to 41 μA/fc after the thermal tests) was observed. Also, a large blemish was added during the tube handling after the last environmental test was completed.

Lot 3 and Lot 4, WX-30691N

The primary vibration sample (72-48-157) and the secondary vibration sample (72-48-172) for Lot 3 failed the vibration test, thereby disqualifying this lot. These tubes (72-48-157 and 72-48-172) developed many target-mesh blemishes. On the same day, the primary vibration sample (72-48-193)of Lot 4 also failed the vibration test. This tube (72-48-193) sustained a broken target. Since no secondary vibration sample was tested due to funding limitations, it has not been possible to requalify Lot 4.

The results from Lots 3 and 4 were very different from our experience with the three tubes from Lots 1 and 2, which were vibrated without adding a single blemish. The WX-30691BRN, which has a different target substrate, also failed the primary vibration test on the same day. This suggests that faulty aluminum-oxide target substrates are not the cause of the failure. It is believed that the failures were not caused by defects in tube design or construction but by handling

the tubes received during the trip to Associated Testing Laboratories from Elmira. The tubes were packed in the same box as the vibration fixture. Subsequent drop tests of tubes packed in the same way showed that a drop of three feet could result in accelerations of 80g. The blemish count on a WX-30691N drop tested at 80g increased from zero to two. Three more spots of less than 3 TVL (smallest spot which is counted as a blemish) were also added. These data indicate that severe mishandling at the airport could have caused the damage which was observed on the vibration samples.

Lot 101 and Lot 102, WX-30691BRN

As noted above, the primary vibration sample (72-48-201) which was to be used for both lots failed the vibration test. This tube had already passed the thermal tests with only a minor drop in sensitivity, (37 μA/fc before the thermal tests to 33 μA/fc after the thermal tests). Since no secondary vibration sample has been tested, it was not possible to requality Lot 101.

The discussion of the cause of the target damage in the section above also applies to this tube. The damage to the WX-30691BRN (72-48-201) was much less than that sustained by the three WX-30691N tubes; the WX-30691BRN was still a useable tube, while the WX-30691N tubes were no longer useable. This is attributed to the superior vibration characteristics of the mesh-supported target substrate.

5.3 Summary of Results

The following comments apply to the qualification efforts.

(1) The qualification status of the separate lots is:

Lot 1	Qualified
Lot 2	Qualified
Lot 3	Disqualified
Lot 4	Incomplete
Lot 101	Incomplete
Lot 102	Incomplete

(2) All of the tubes which failed were vibrated on one day. The cause of the failure is believed to be due to poor handling when the tubes were transported to and from the vibration facility.

(3) The tube with a mesh-supported target substrate (WX-30691BRN) was less damaged than the tubes with an aluminum-aluminum oxide substrate (WX-30691N). This fact supports the contention that the mesh-supported target substrate has superior vibration characteristics.

6. CAMERA TUBE LIFE

6.1 Introduction

As specifically requested in the contract, this section presents information about the expected life of the WX-30691N and the WX-30691BRN tubes. These tubes are Secondary Electron Conduction (SEC) tubes manufactured specifically for the ATM Program. Much of these test data were obtained on tube types other than the WX-30691N and the WX-30691BRN. However, all the information was obtained from SEC tubes with an S-20 photocathode and an indirectly-heated, one-watt thermionic cathode as used in the WX-30691N and the WX-30691BRN. The data indicate that the nature of the substrate does not affect the life of the tube.

The life test data are presented in graphs showing tube survival percentage versus life test duration. The sample size is also recorded on the plot, since it changes during the period as tubes which have not failed are retired.

6.2 Failure Modes

Previous experience suggests that tube failures can be separated into the following categories:

(A) SEC Target Performance

(B) Thermionic Cathode Emission

(C) Photocathode Emission

(D) Other (including vacuum integrity, electrical open circuits or shorts, internal arcing, etc.).

The term failure is used to describe a tube whose performance has decreased below a certain specified level to be defined later. It does not necessarily imply a catastrophic failure or even a complete loss of picture. The tube continues to be called a failure even though its performance may return to the acceptable level later in life. This type of performance is typical of tube sensitivity which often goes through a minimum early in life. The sensitivity then increases and may reach or exceed the sensitivity measured at the start of life.

It cannot be emphasized too strongly that the failure criteria used in this analysis are quite stringent. Experience with SEC camera tubes used in the studio broadcast color cameras has shown that individual tubes will continue to generate pictures of a level adequate to satisfy the high aesthetic standards of the broadcast profession after as many as 8000 hours of operation. This comment is particularly relevant to the SEC target performance data shown in Figure 6.1. It should be noted that though this graph shows 100% failure rate after 6000 hours of operation, all of the tubes involved in this test were still producing a television picture at the conclusion of the test.

The following performance criteria were chosen to define failure of the tube:

(1) A drop in tube sensitivity below 15 μA/fc which is 50% of the minimum specified level for the ATM Program.

(2) Observation of objectionable target grain or target damage.

(3) An increase in tube lag above 20%, which is twice the maximum specified level.

(4) An increase of more than 10 volts on the control grid, G_1, to discharge a 150 nA signal. An example is: If a G_1 bias of -60 volts initially results in a beam which can just discharge a signal of 150 nA, the thermionic cathode would be classified a failure when a G_1 bias of -50 volts results in a beam which cannot discharge a signal of 150 nA.

(5) A slump in photoresponse below 70% of the level measured 3 weeks after the tube was made. Three weeks was chosen as the minimum stabilization period between making the tube and shipping it.

(6) Other changes causing the tube to perform at less than 90% of its minimum specified level. This criterion covers miscellaneous failures that are not included in the preceding five items.

Items 1, 2, and 3 are used to define SEC target life. Item 4 defines thermionic cathode life. Item 5 defines photocathode life. Item 6 defines other causes of tube failure.

Failure Mode (A) - SEC Target Performance

The SEC target life test data are listed in Figure 6.1. The end of life duration has been adjusted to reflect operation with an average signal current of 10 nA obtained with a 1/30 second integration time and 1/30 second frame time; that is, at normal TV rates. Deterioration

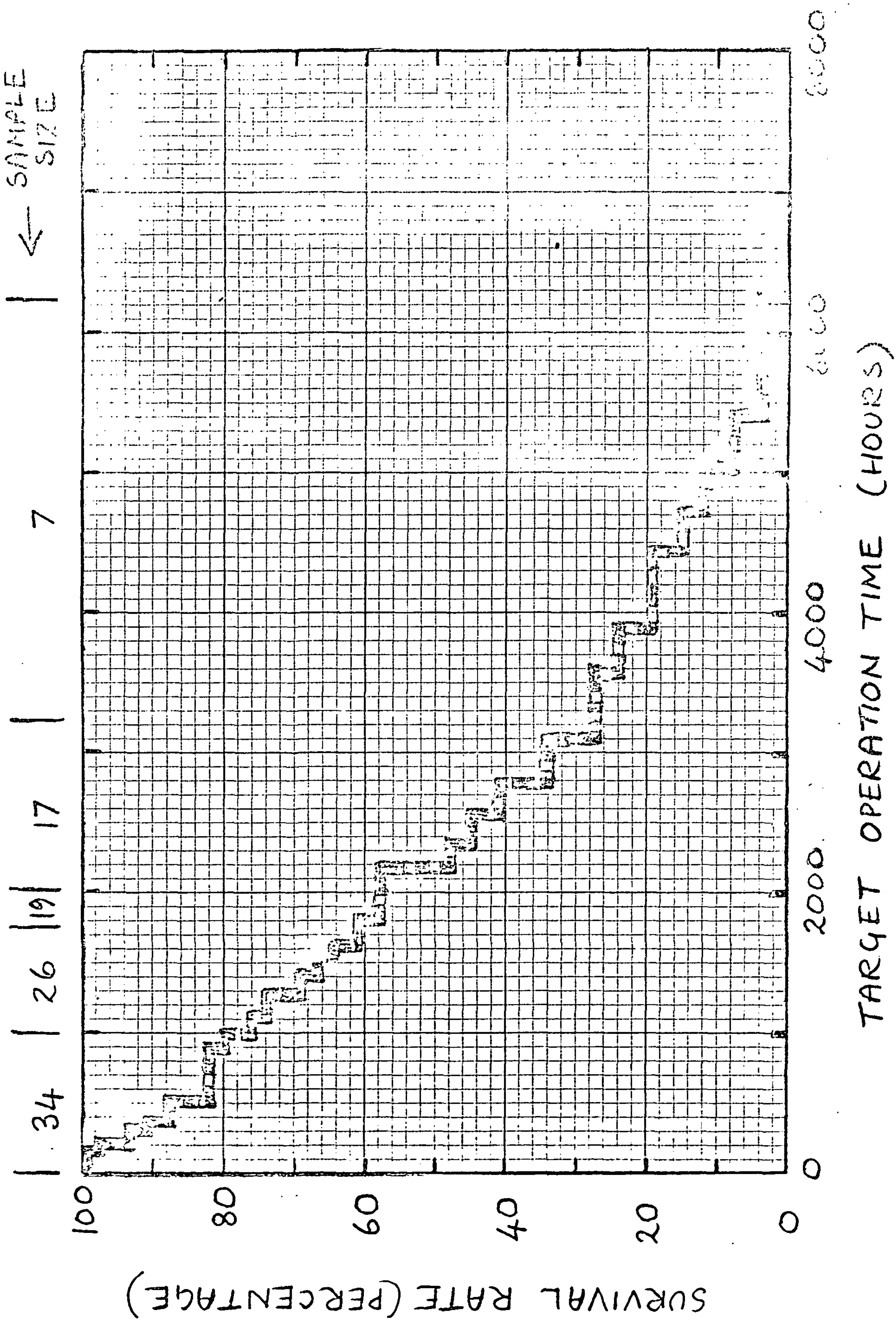

SAMPLE SIZE
34
26
19
17
7
TARGET OPERATION TIME (HOURS)
0
2000
4000
6000
8000
SURVIVAL RATE (PERCENTAGE)
100
80
60
40
20
0

FIGURE 6.1

of the SEC target occurs only when the tube is exposed to light. The rate of deterioration is proportional to the light level or the signal current (since this is also proportional to light level). Thus, all of the life times shown in Figure 6.1 will be halved if the average signal current is increased to 20 nA. When using Figure 6.1, it should be noted that a scene consisting of half light (giving a 20 nA signal current) and half dark (giving a zero signal current) picture points will average to a 10 nA loading. Similarly a scene consisting of one-fifth light (giving a 25 nA signal current) and four-fifths dark (zero signal current) picture points will average to a 5 nA loading. In this latter case, the lifetimes shown in Figure 6.1 would be doubled.

To obtain these data, SEC camera tubes were operated in a dynamic life test set at recommended voltages and at an ambient temperature of about 28°C. The photocathode was exposed to a uniform illumination on the raster area. The tubes were periodically removed from the life test set and retested to check their performance. The tube performance was then compared to its performance before life test to determine whether the tube had failed.

Failure Mode (B) - Thermionic Cathode Emission

The thermionic cathode emission data are shown in Figure 6.2. SEC camera tubes were operated in a cathode life test set at an ambient temperature of about 28°C. The recommended voltages were applied to the cathode, the heater, and G_2. G_1 bias was adjusted to give a 0.5 mA

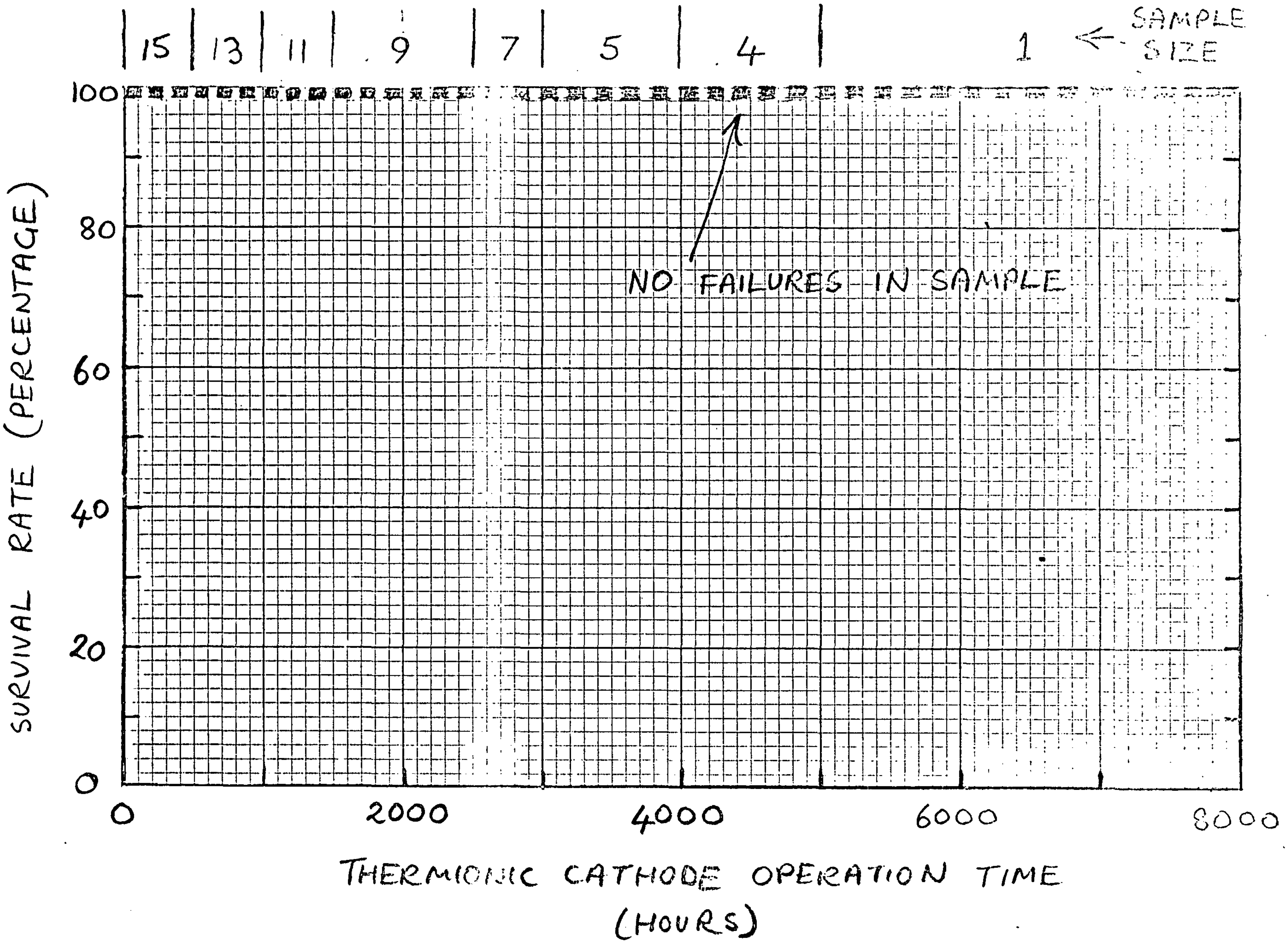

15
13
11
9
7
5
4
1
SAMPLE SIZE
NO FAILURES IN SAMPLE
100
80
60
40
20
0
SURVIVAL RATE (PERCENTAGE)
0
2000
4000
6000
8000
THERMIONIC CATHODE OPERATION TIME (HOURS)

FIGURE 6·2

cathode current. A 0.5 mA cathode current will easily discharge a 150 nA signal current. None of the other tube electrodes were connected. The tubes were periodically removed from the cathode life test set and retested to check their performance. The tubes' discharge capabilities were then compared to their performance before life test to determine whether the tubes had failed.

All of the data were obtained on the WX31381BRN type. These SEC tubes have the same cathode and lower gun structure as the WX30691N and WX30691BRN; consequently their performance is directly applicable.

The performance of the thermionic cathode is very good, as can be seen from the lack of any failure on tubes tested to 8000 hours. Historically, the thermionic cathode has shown good performance on the tubes subjected to full operational life test; that is, tubes producing actual television pictures. Only one of the approximately thirty tubes tested has shown a cathode emission problem even before the cathode life was improved by reducing the cathode temperature.

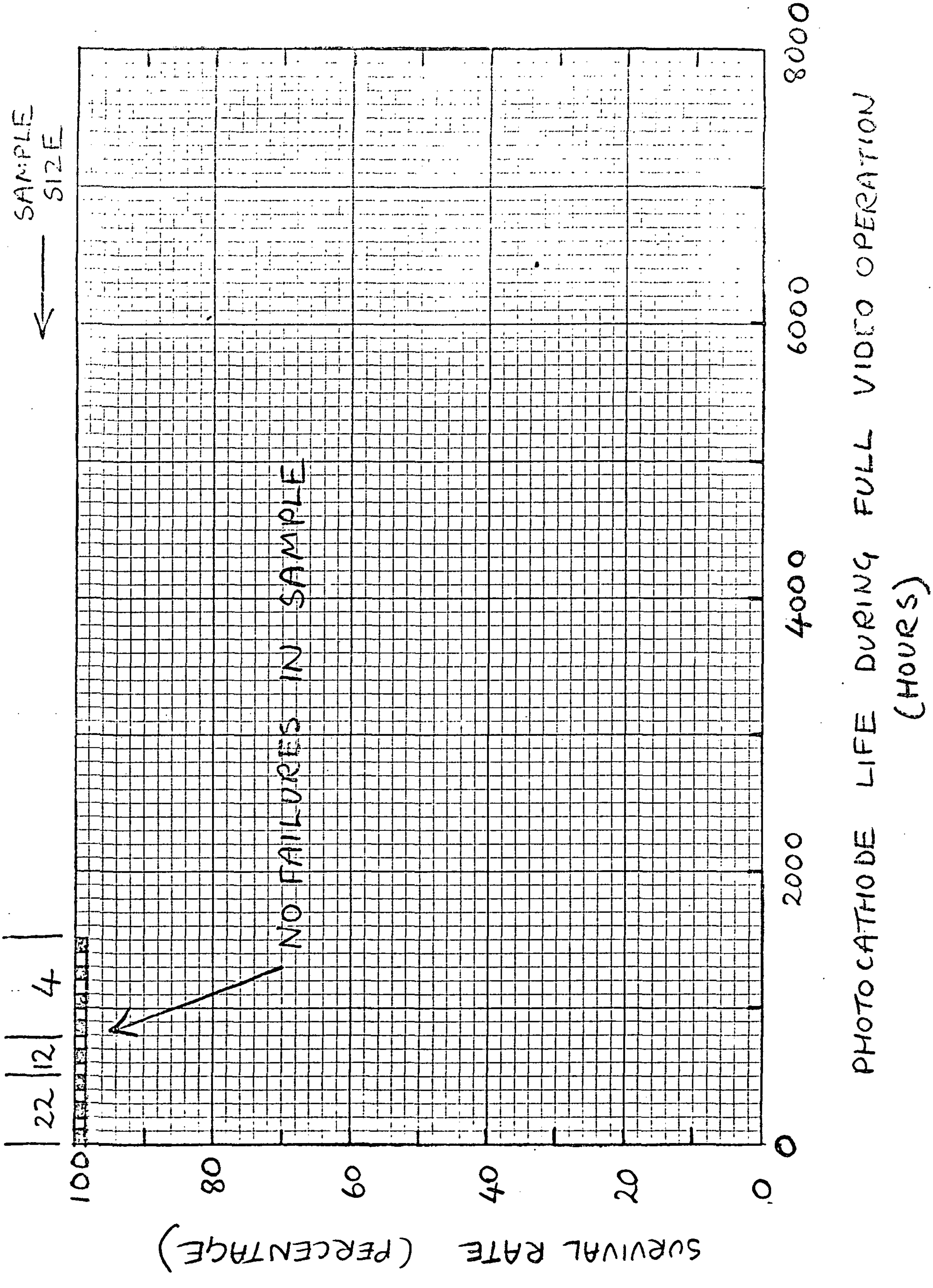
Failure Mode (C) - Photocathode Emission

Over the last few years, a considerable amount of operational and shelf life data for the S-20 photocathode have been compiled. Operational life testing (that is, with the tube producing actual television pictures) has been performed from 500 to 1500 hours, and shelf life testing has been carried to 35,000 hours for one group of twenty WX30691N tubes built in 1968 for the ATM Program.

The results for 1970 commercial SEC camera tubes during full video operation and 1972 WX30691N ATM tubes during shelf life are shown in Figures 6.3 and 6.4. In addition to this information, the photoresponses of twenty (20) SEC tubes of the WX30691N type manufactured in 1968 have been measured between 1968 and January 27, 1972. These 20 tubes made up a comprehensive sample of tube histories. Included were tubes used for cathode life testing (gun operation only), tubes for video life testing, tubes for high temperature storage experiments (+85°C for 48 hours), and tubes that have been stored at room temperature since 1968.

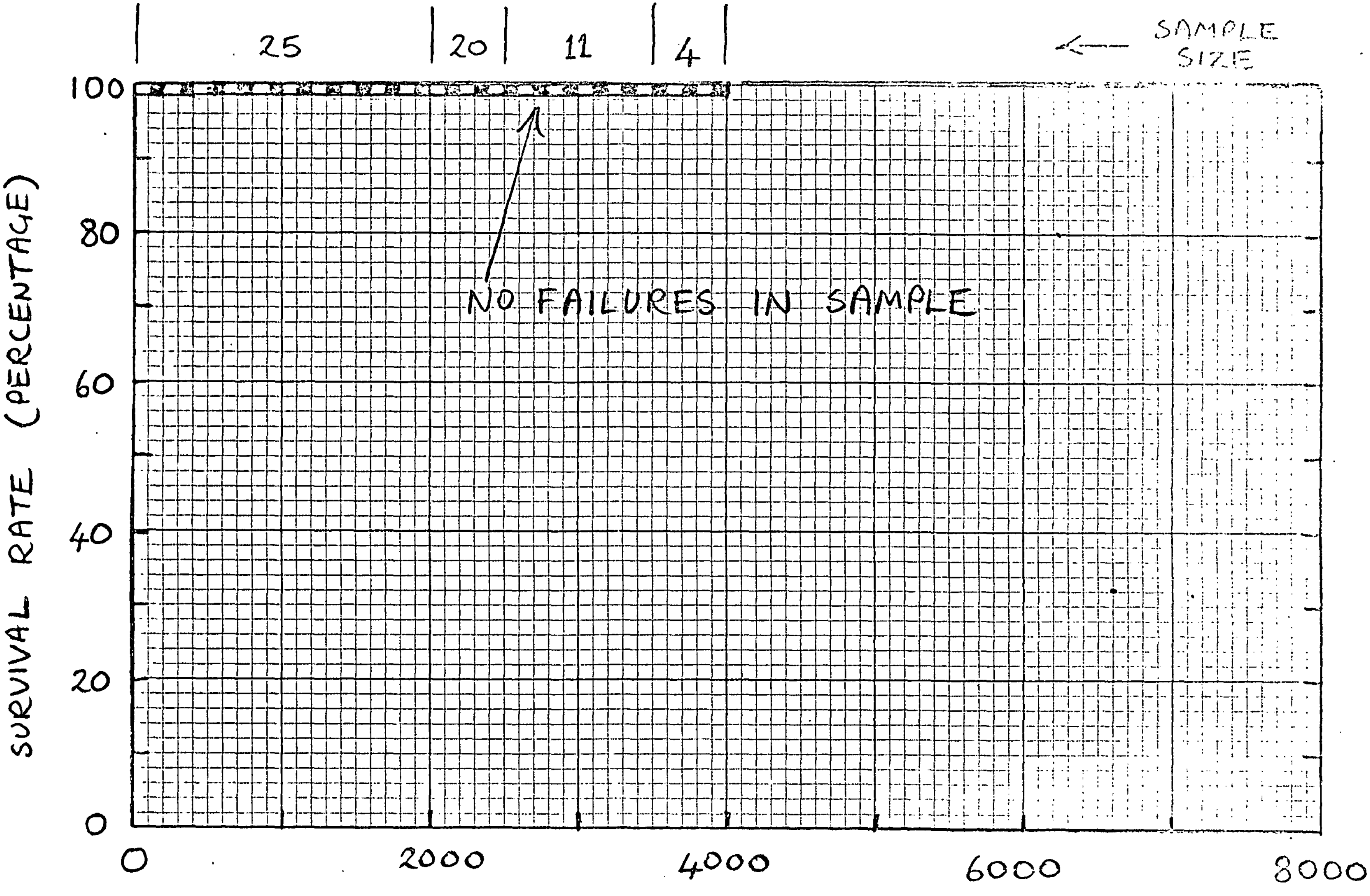
The average photoresponse for the sample dropped from 164 μA/lm in 1968 to 138 μA/lm in 1972. The average decrease calculated as a percentage of the initial photoresponse was 15%. Distributions of individual tube values for the sample as measured in 1968 and 1972 are shown in the form of histograms in Figure 6.5. The recorded values of photoresponse are shown as a function of time in Table 6.1.

It may be concluded from the available data that a tube of the WX30691N type may experience a drop in photoresponse of approximately 15% over a four year period with a larger fraction of this drop occurring in the first year. It should be noted that, in some cases, techniques are available for the restoration of the photoresponse to close to its original value.



1970 COMMERCIAL SEC CAMERA TUBES

FIGURE 6·3



PHOTOCATHODE SHELF LIFE (HOURS)

1972 WX-30691 N ATM TUBES

FIGURE 6.4

PHOTOCATHODE STABILITY FOR WX-30691N SEC TUBES MANUFACTURED IN 1968

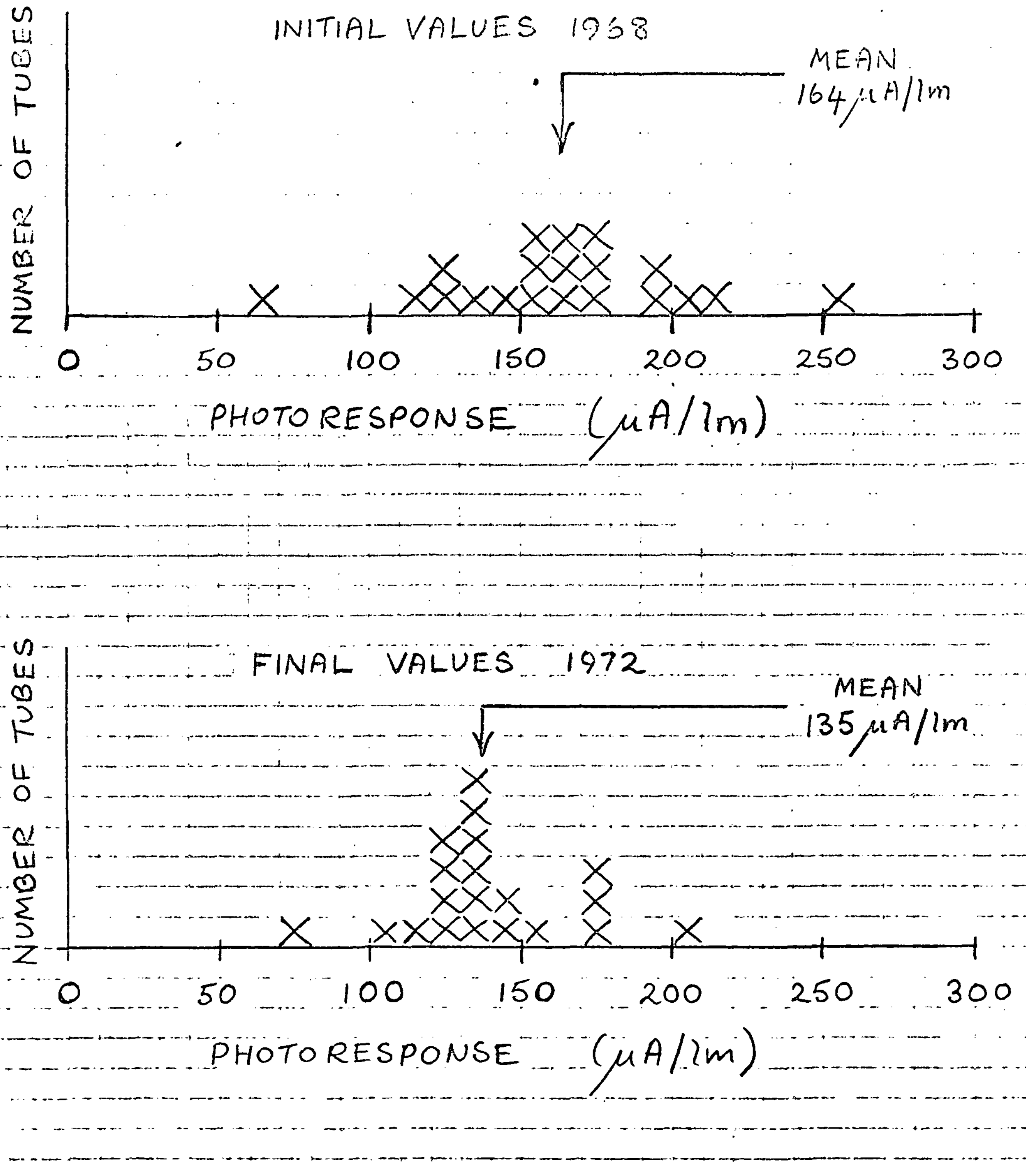


FIGURE 6·5

TABLE 6.1

PHOTORESPONSE STABILITY FOR WX30691N SEC TUBES MANUFACTURED IN 1968

RESPONSE IN µA/lm

SERIAL NO.	J 1968	D	J 1969	D	J 1970	D	J 1971	D	J 1972	D
68-13-052N	255	-V-							200	
68-26-202	155	-V-							127	
68-35-014N		218		T 191 178					144	
68-35-035NC		203			-K-				156	
68-35-048		135		T 135 132					121	
68-39-104		174			-K-				138	
68-39-117		122-V-							116	
68-39-127		166		T 154 160					146	
68-39-129		150		T 148 133					131	
68-39-155		156		121					122	
68-39-157		127-V-							130	
68-39-173		167		168					172	
68-39-174		160-K-		137					123	
68-39-177		195-V-							175	
68-39-194		170-K-							134	
68-39-200		178		148-V-		136			134	
68-39-214		66-V-							79	
68-39-222		191-V-155							176	
68-39-230		149							130	
68-39-240		115		106-K-					101	

-K- Cathode Life Test; T Temperature Cycle; -V- Video Life Test

Failure Mode (D) - Other Causes

During 16,500 hours of full operational life test involving twenty-one (21) tubes, only one (1) tube failed for "other causes" (actually for an ion burn of the photocathode). Another twenty (20) WX30691N tubes, which were in inventory for 15 months from October 1967 to January 1969 (giving a total of 216,000 hours of shelf life), showed no failures due to loss of vacuum.

6.3 Conclusions

The data presented in this Section may be used to anticipate survival rates for more complex "real life" situations. Consider, for example, a camera tube which will be subjected to the following operational envelope:

Total operational and non-operational period	8,000 hours
Thermionic cathode operational period	4,000 hours
Video operational period at an average signal current of 5 nA	2,000 hours

From the data presented earlier in this Section, it is possible to estimate approximate survival rates for the various failures modes involved.

Photocathode survival rate for 8,000 hour period	= 1.00
Thermionic cathode survival rate for 4,000 hour period	= 1.00
Target survival rate for 2,000 hours at 5 nA which is equivalent to 1,000 hours at 10 nA	= 0.75
Total Survival Rate 1.00 x 1.00 x 0.75	= 0.75

APPENDIX I

BURN IN SEC CAMERA TUBES

WESTINGHOUSE ELECTRO-OPTICAL

ENGINEERING MEMO #85

From : Elmira ETD - E-O Eng.Dept.
Dial : 224-8349
Date : April 19, 1973
Subject: Burn in SEC Camera Tubes

ELECTRO-OPTICAL ENGINEERING MEMO # 85

ELMIRA WORKS

W. PLUMMER

cc: R. Beyer
D. Doughty
R. Harder
G. Helt
A. Laponsky
P. Lindeqvist
R. Malanoski
J. Pietrzyk
L. Vaughn
W. Whitson

The illumination overload conditions leading to permanent white burns in the targets of SEC camera tubes have been reported in two previous publications.[1,2] This memorandum describes the lesser illumination overloads that produce temporary dark burns in the targets of SEC camera tubes.

The permanent white burns are localized areas of dark current that are visible in both light and dark field scenes. The temporary dark burns are caused by a loss of gain in the target. Thus, they are only visible in a light field scene. Figures 2 and 3 show the magnitude of the dark burn as a function of photocathode illumination (in footcandles) and exposure time. These results were obtained with a standard WL-30691 and a WL-30691BR at a photocathode voltage of 7 kV. It should be noted that illumination levels for normal operation are no more than 10^{-2} footcandles at this voltage.

The information shown in Figures 2 and 3 was measured immediately after the removal of the illumination overload. It is presented as the signal in the area exposed to the overload relative to the signal in an unexposed area measured in the presence of a uniform normal illumination level (3×10^{-3} footcandles). Examination of Figures 2 and 3 shows that the Standard and BR tubes react in the same way to the overload condition producing a dark burn. However, at the point where a white burn begins to appear they behave differently. Thus we may conclude:

(1) Dark burn effects on Standard and BR are similar.

(2) White burn effects on Standard and BR are different with the BR tube, as its name suggests, being more resistant to a white burn.

1. "Preliminary Results of Burn Tests on the WL-30691" Image Tube Engineering Memorandum # 43, May, 1970
2. "The Burn Resistant SEC Camera Tube", Electro-Optical Design Conference, September, 1970

Figures 4 through 10 show the recovery of the tube after an exposure to an overload producing a dark burn. These measurements were made with a photocathode voltage of 7 kV and the tube was operated at a light level of about 5×10^{-3} footcandles during the burn recovery period. The time taken for the burn to disappear (ie. for the relative signal in the burn image to return to 100%) is called the recovery time. Figure 11 shows the relation between the recovery time and the overload exposure time for different overload illumination levels.

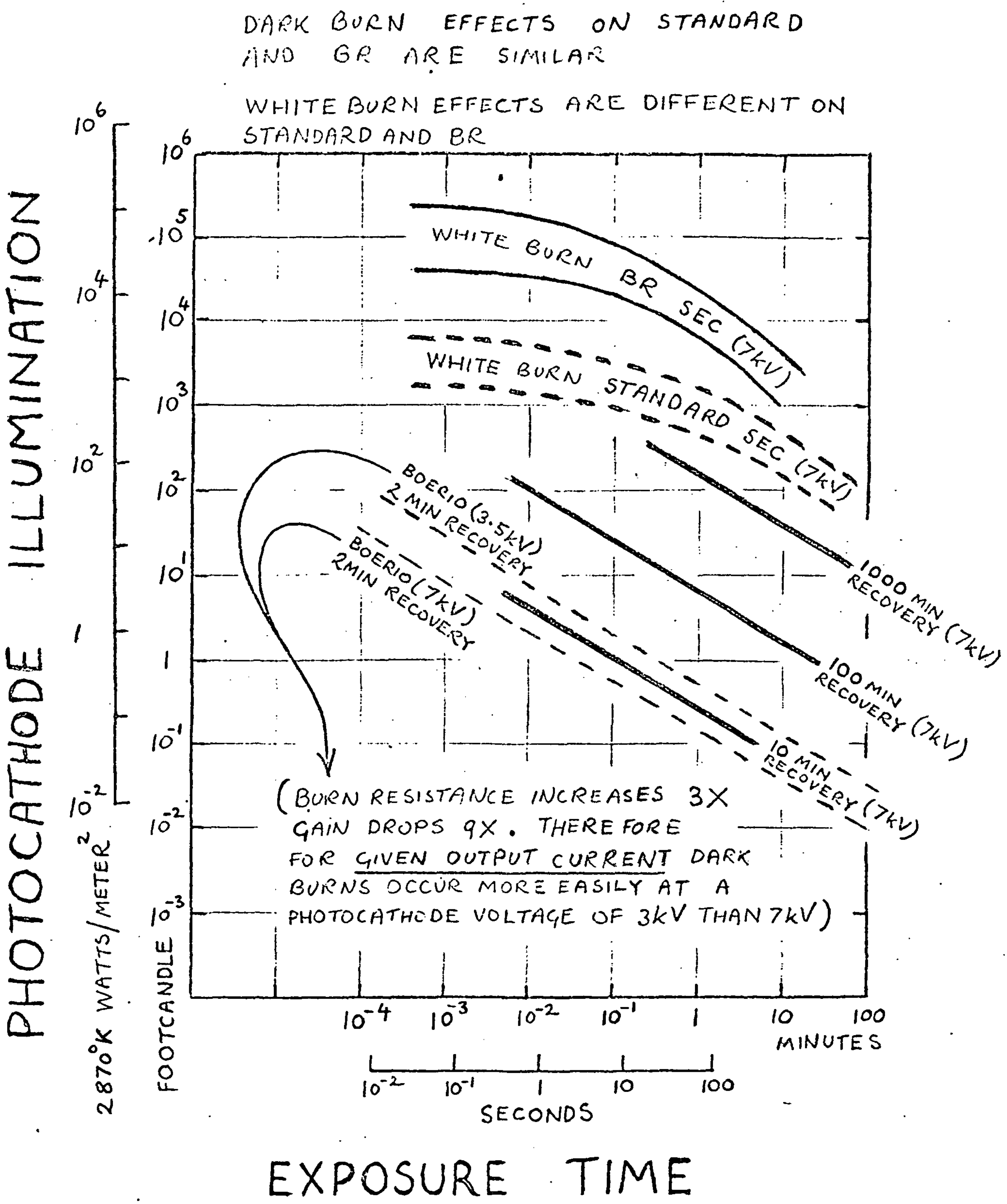
The results are summarized in Figure 1. This diagram shows the tolerance to different overload exposure illuminations and times for both white and dark burns. For example, consider an overload exposure of 10 minute duration. A 10^{-1} footcandle overload will produce a dark burn that will recover in about 1 0 minutes. White burns (not recoverable) will be produced at 300 and 2000 footcandles respectively in the Standard and BR tubes. The dotted lines on the diagram show data reported earlier by Boerio. His dark burn information was for a 2 minute recovery. It is in fair agreement with the present measurements. Boerio made measurements at both 7 kV and 3.5 kV on the photocathode. Analysis of this data shows that <u>for a given output signal current</u>, burns occur 3 times more easily at 3.5 kV than at 7 kV.

Martin Green

Martin Green
Advisory Engineer

/sc

Att.



DARK BURN EFFECTS ON STANDARD AND BR ARE SIMILAR
WHITE BURN EFFECTS ARE DIFFERENT ON STANDARD AND BR
WHITE BURN BR SEC (7kV)
WHITE BURN STANDARD SEC (7kV)
BOERIO (3.5kV) 2 MIN RECOVERY
BOERIO (7kV) 2MIN RECOVERY
1000 MIN RECOVERY (7kV)
100 MIN RECOVERY (7kV)
10 MIN RECOVERY (7kV)
(BURN RESISTANCE INCREASES 3X GAIN DROPS 9X. THEREFORE FOR GIVEN OUTPUT CURRENT DARK BURNS OCCUR MORE EASILY AT A PHOTOCATHODE VOLTAGE OF 3kV THAN 7kV)
PHOTOCATHODE ILLUMINATION
2870°K WATTS/METER²
FOOTCANDLE
10^6
10^5
10^4
10^3
10^2
10^1
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10
100
MINUTES
SECONDS
EXPOSURE TIME

FIG 1

STANDARD SEC (7kV)

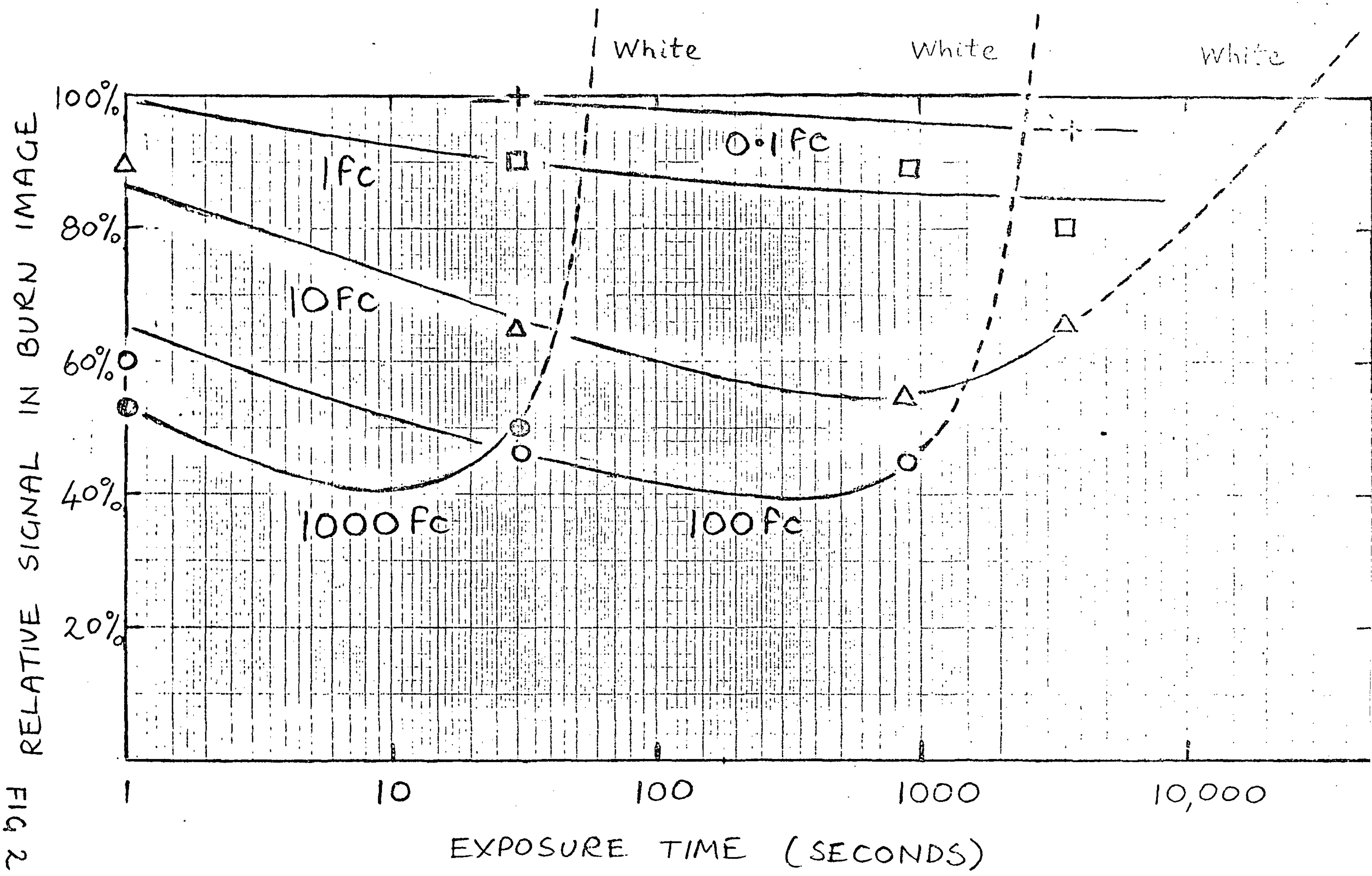


FIG 2

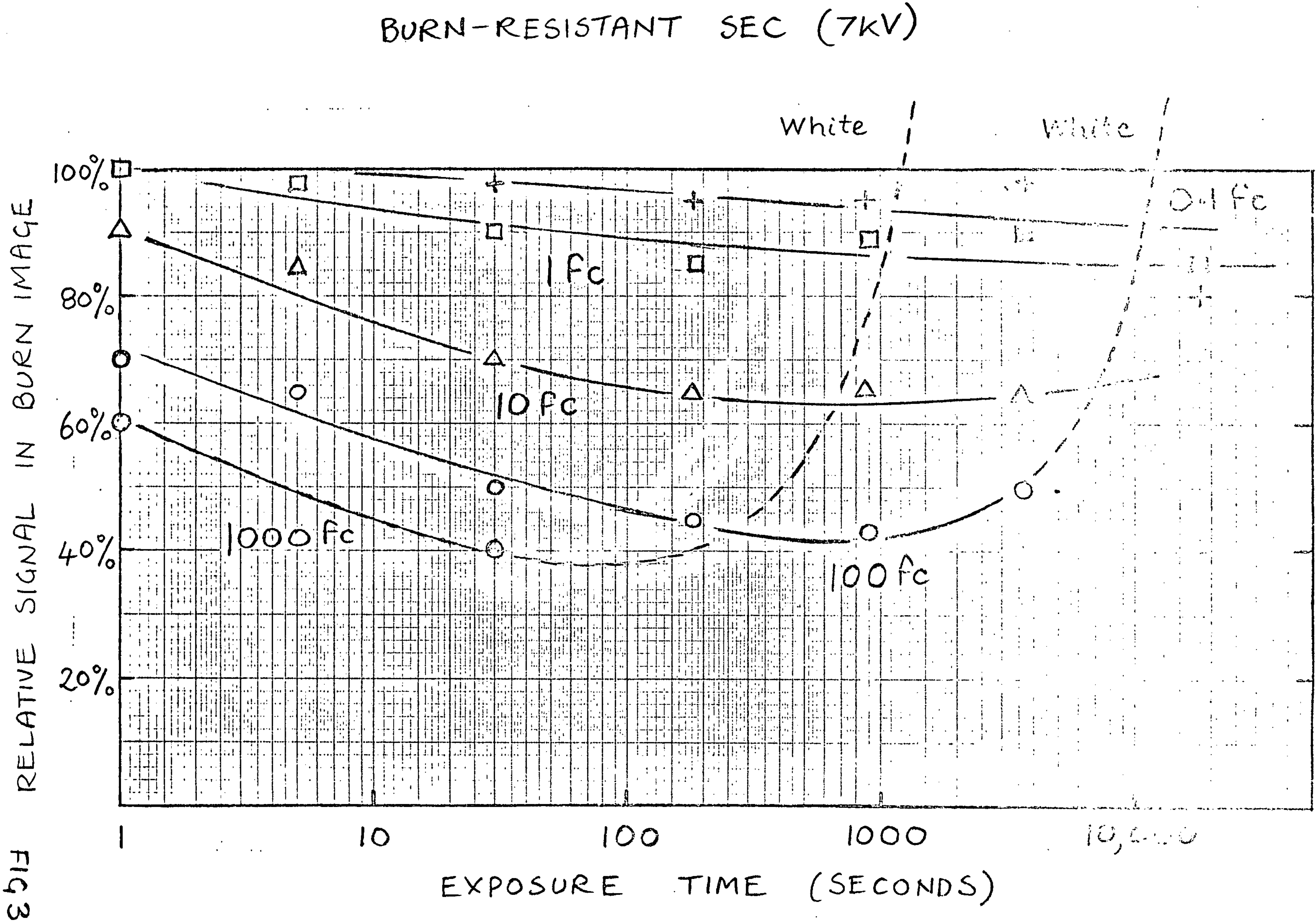

BURN-RESISTANT SEC (7KV)
White
White
0·1 fc
1 fc
10 fc
100 fc
1000 fc
100%
80%
60%
40%
20%
RELATIVE SIGNAL IN BURN IMAGE
1
10
100
1000
EXPOSURE TIME (SECONDS)

FIG 3

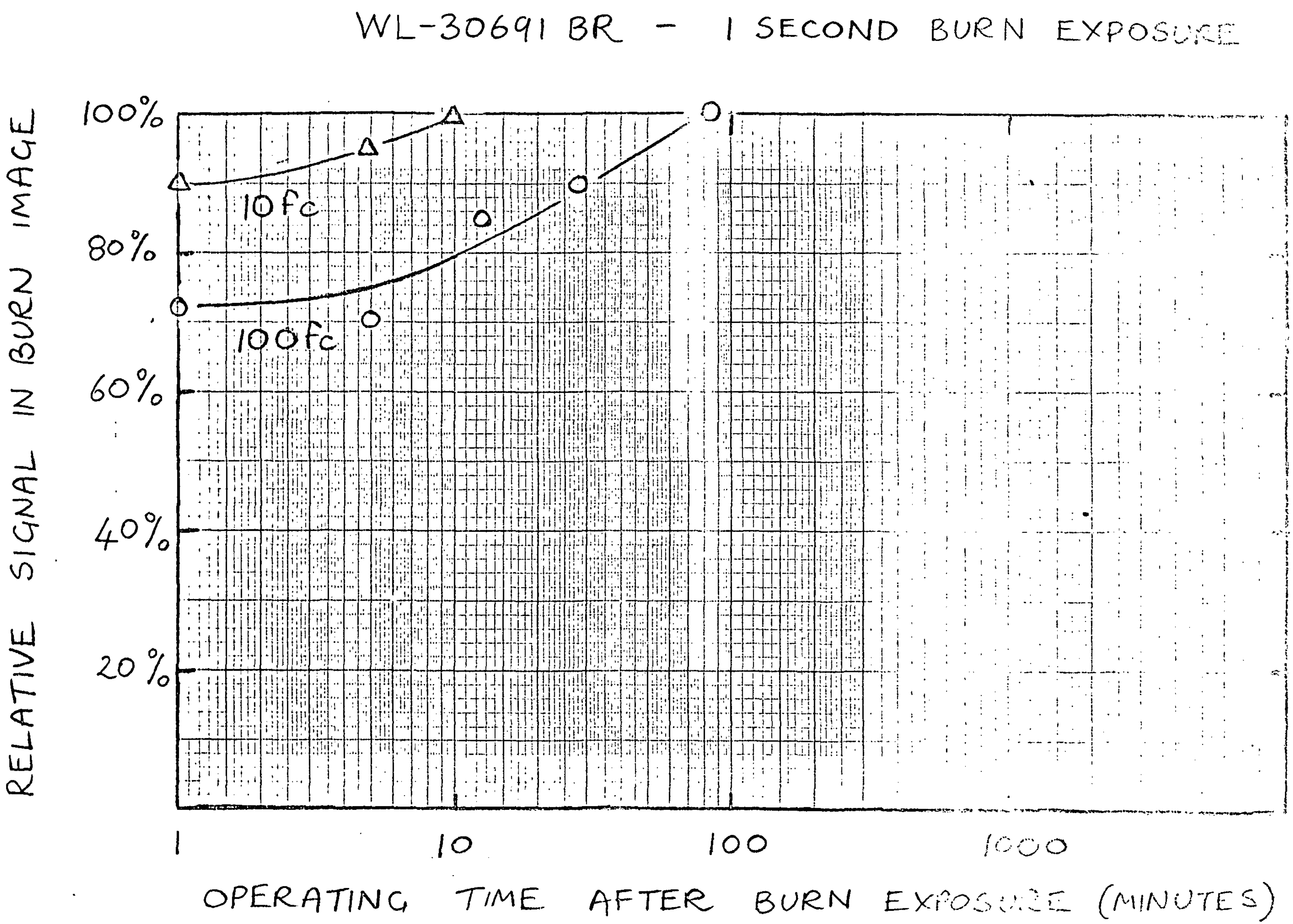

WL-30691 BR - 1 SECOND BURN EXPOSURE
RELATIVE SIGNAL IN BURN IMAGE
100%
80%
60%
40%
20%
10fc
100fc
1
10
100
1000
OPERATING TIME AFTER BURN EXPOSURE (MINUTES)

FIG 4

WL-30691 BR – 5 SECOND BURN EXPOSURE

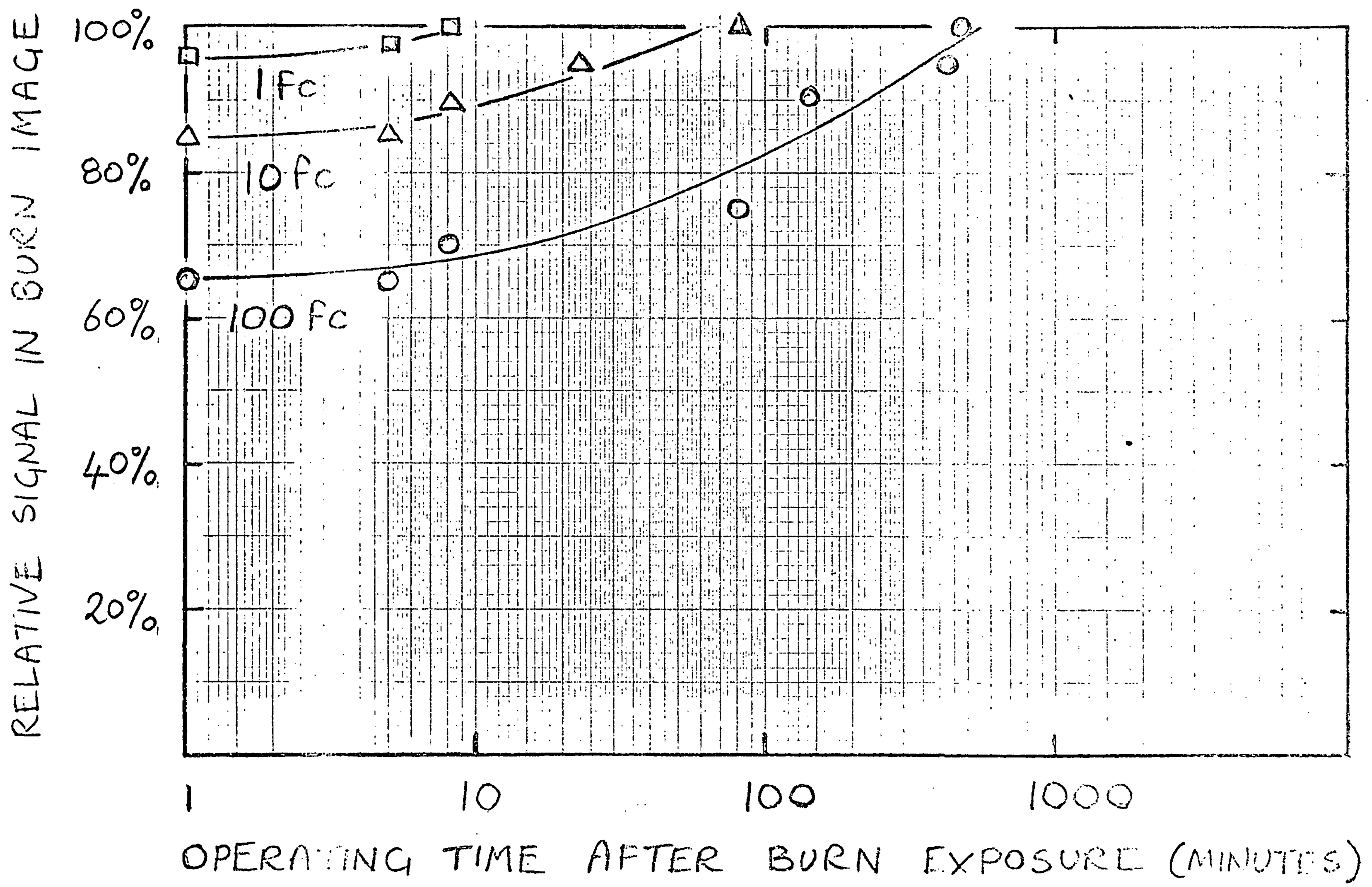


FIG 5

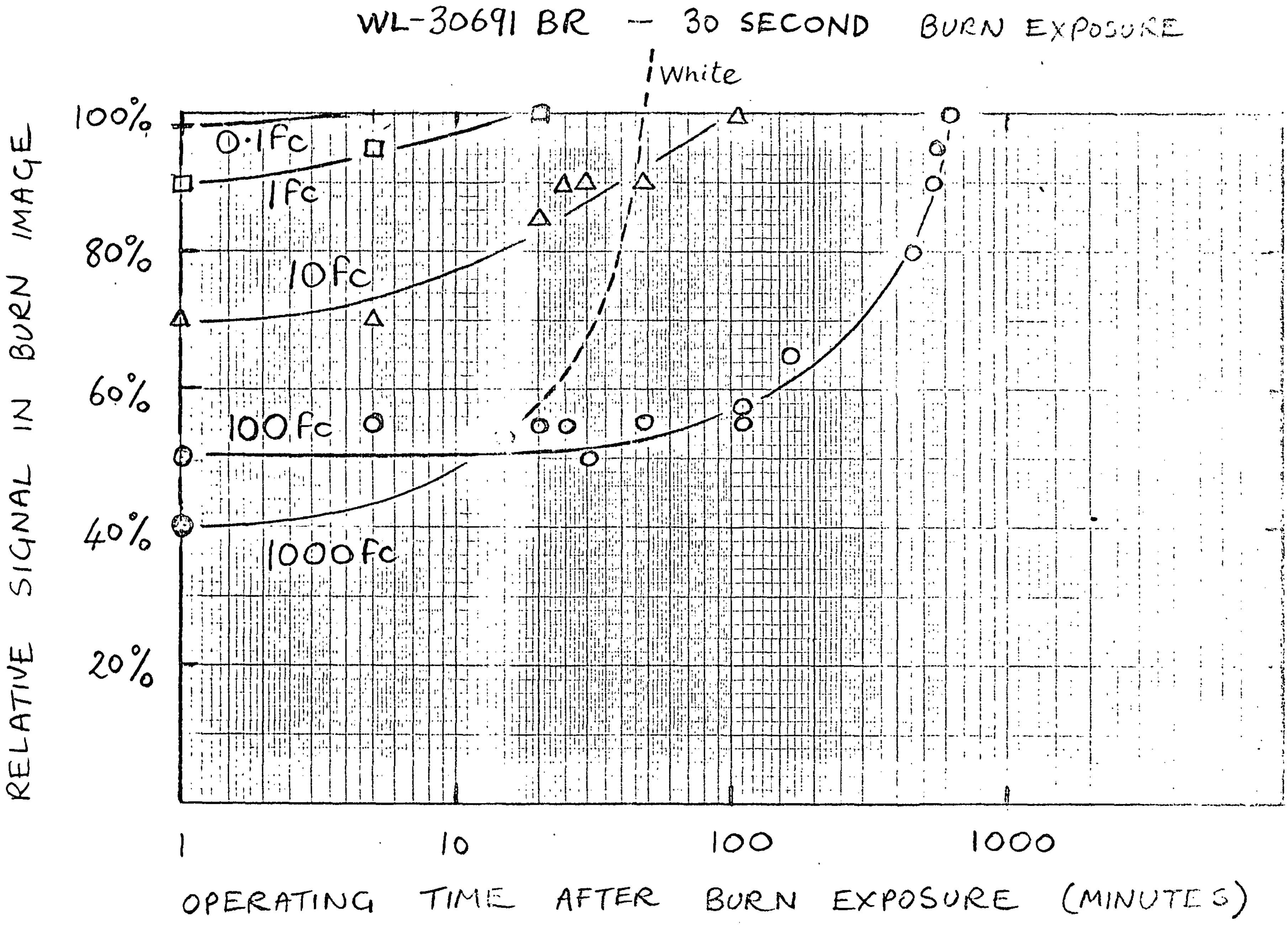

WL-30691 BR — 30 SECOND BURN EXPOSURE
White
100%
80%
60%
40%
20%
0.1fc
1fc
10fc
100fc
1000fc
RELATIVE SIGNAL IN BURN IMAGE
1
10
100
1000
OPERATING TIME AFTER BURN EXPOSURE (MINUTES)

FIG 6

WL-30691 BR — 3 MINUTE BURN EXPOSURE

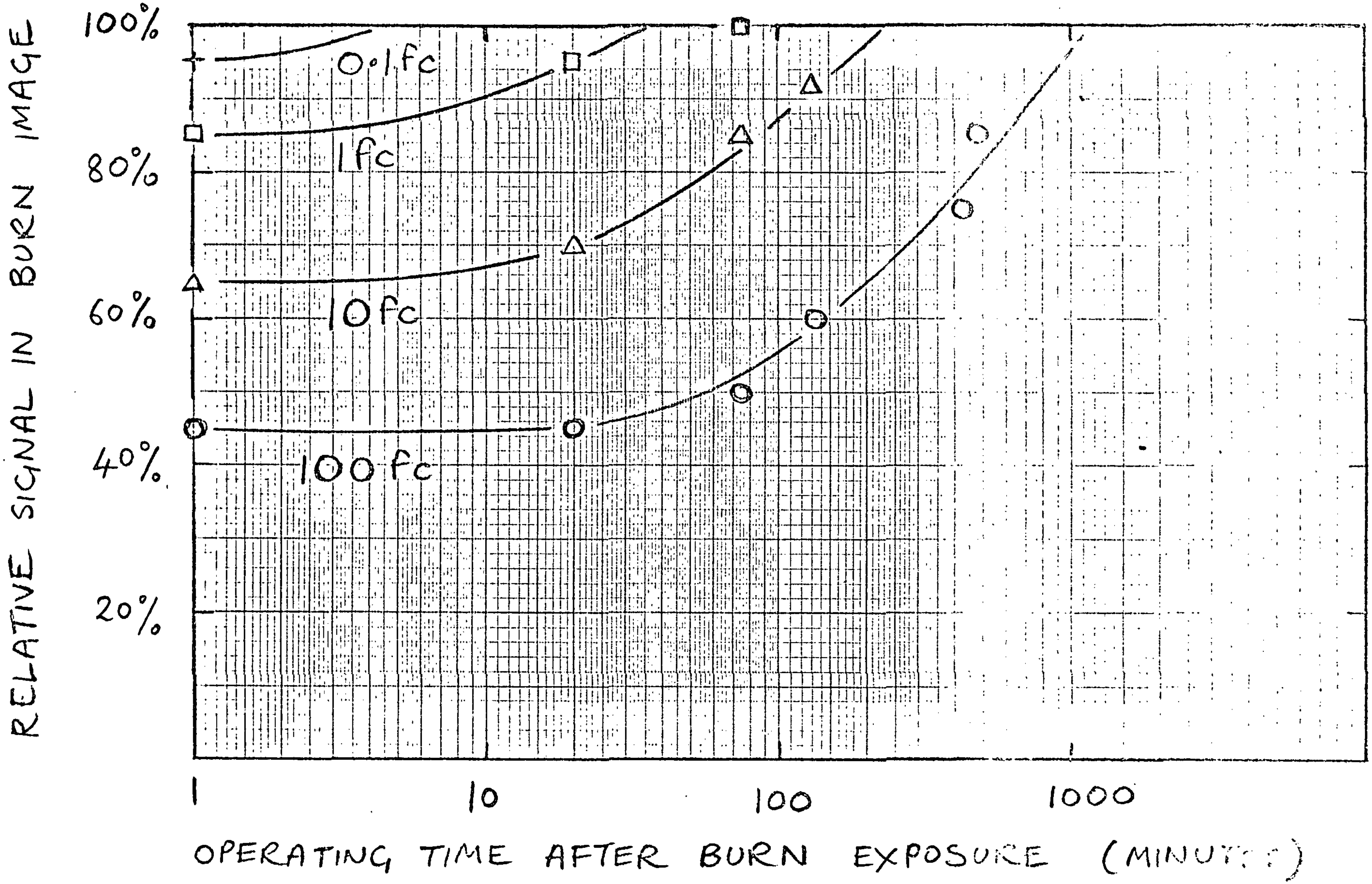
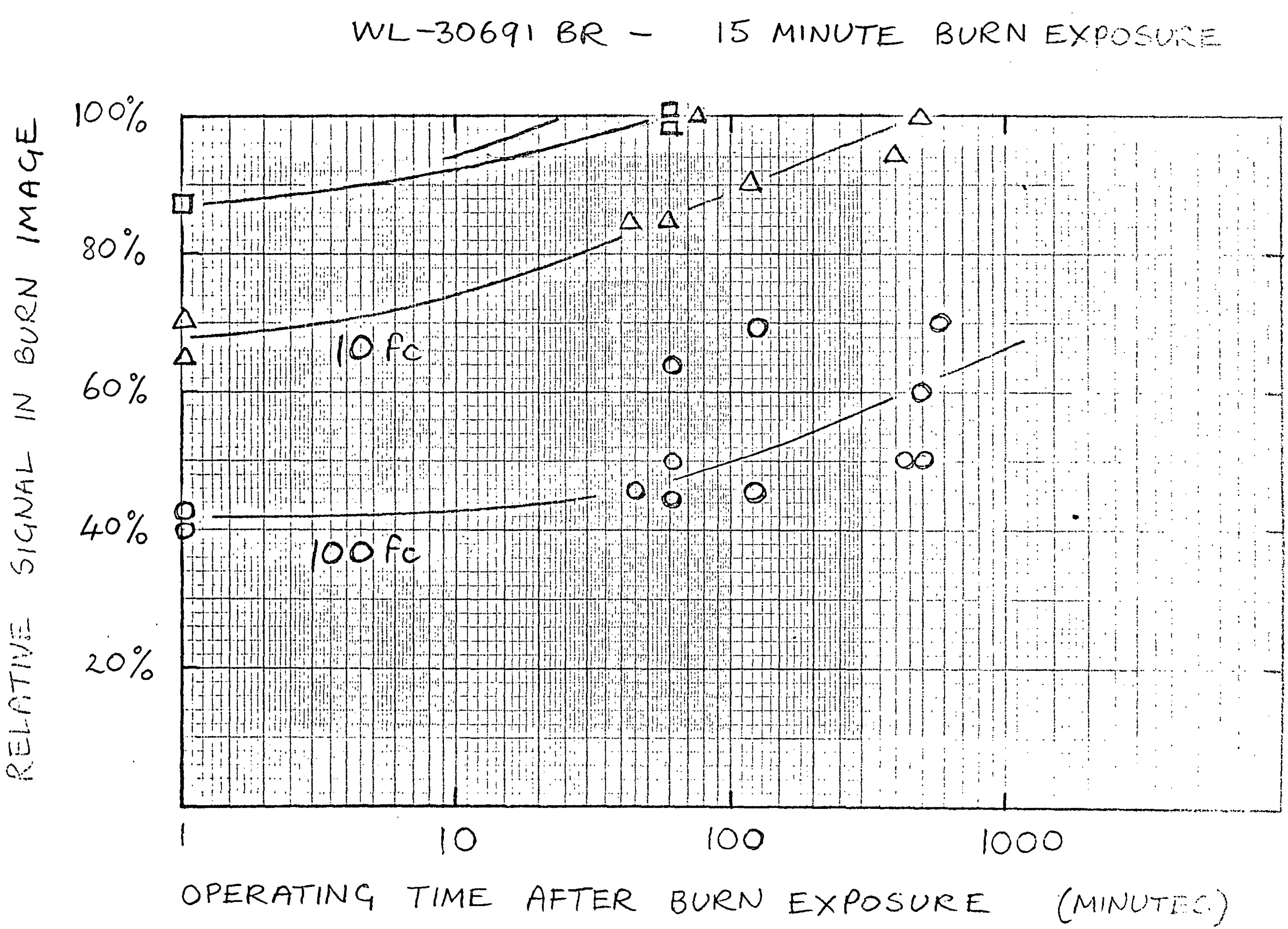
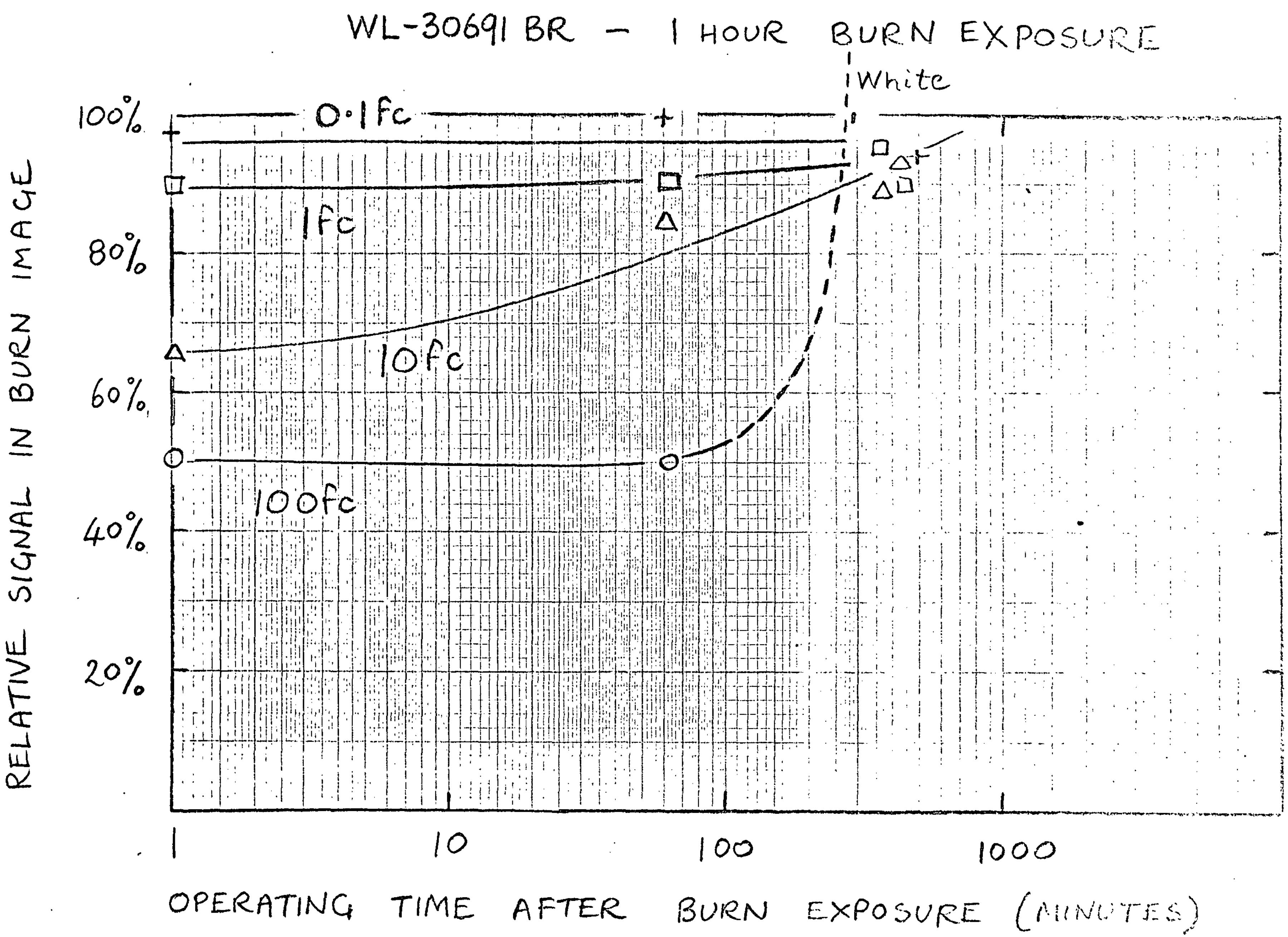


FIG 7



WL-30691 BR - 15 MINUTE BURN EXPOSURE
100%
80%
60%
40%
20%
RELATIVE SIGNAL IN BURN IMAGE
10 fc
100 fc
1
10
100
1000
OPERATING TIME AFTER BURN EXPOSURE (MINUTES)

FIG 8



WL-30691 BR – 1 HOUR BURN EXPOSURE
White
0·1fc
1fc
10fc
100fc
100%
80%
60%
40%
20%
RELATIVE SIGNAL IN BURN IMAGE
1
10
100
1000
OPERATING TIME AFTER BURN EXPOSURE (MINUTES)

FIG 9

WL-30691 BR - 5 HOUR BURN EXPOSURE

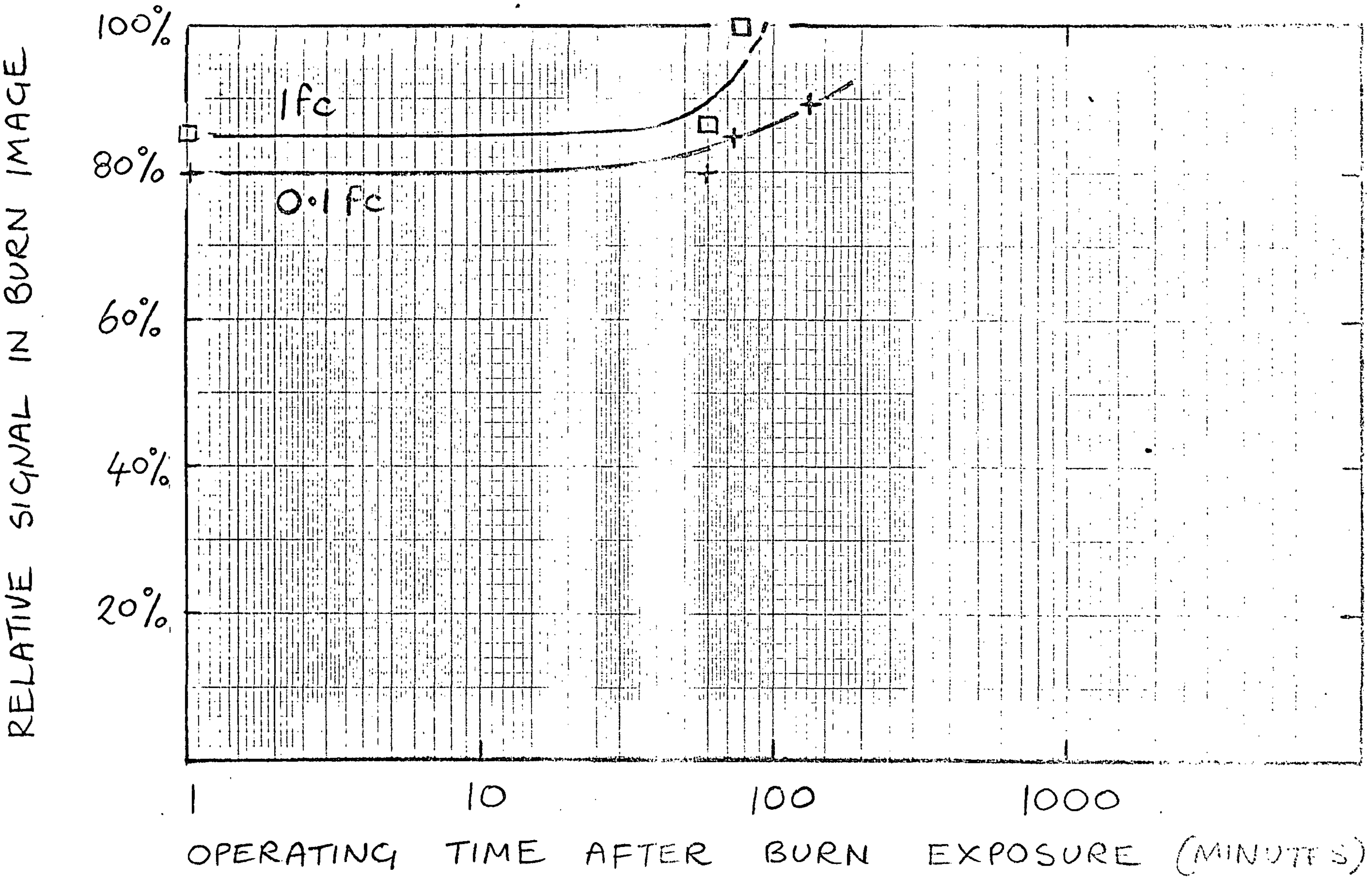
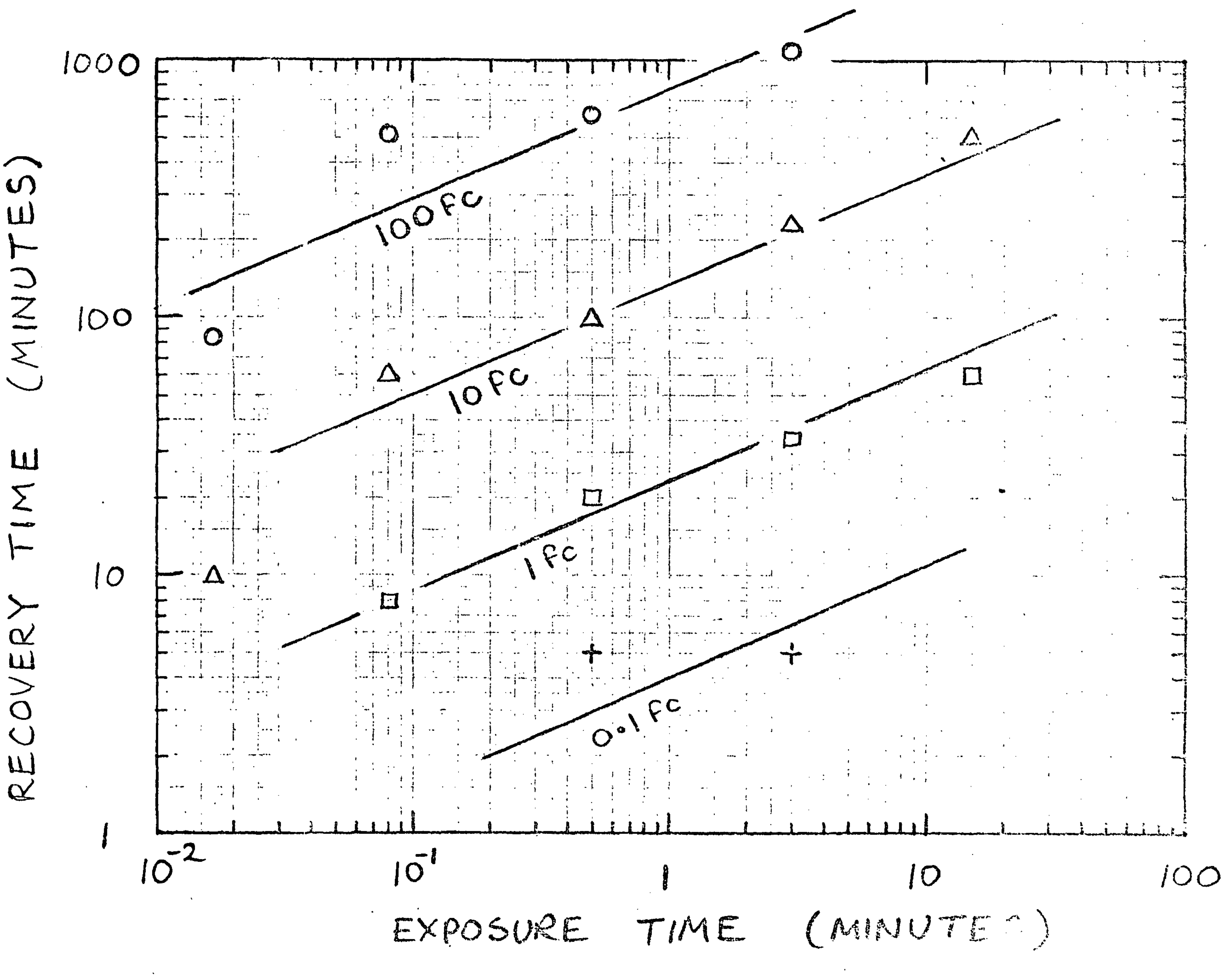


FIG 10



1000
100
10
1
100fc
10fc
1fc
0·1fc
RECOVERY TIME (MINUTES)
10^{-2}
10^{-1}
1
10
100
EXPOSURE TIME (MINUTES)

FIG 11